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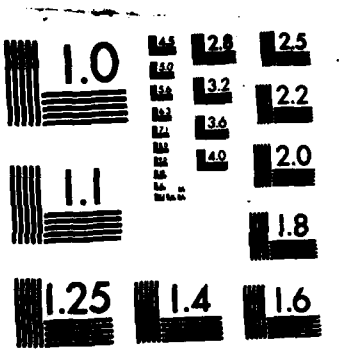

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Date: April 27, 1983

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Contractor: Cornell University

Principal Investigator: Richard L. Liboff

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A review of work performed under contract AFOSR 78-3574 during the '82-'83 support interval is presented. A list of titles and abstracts of technical reports issued during this period is included. A brief summary is presented of lectures delivered at the University of California on contractual research. The report concludes with a description of ongoing research.

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Abstract

A review of work performed under contract AFOSR 78-3574 during the '82-'83 support interval is presented. A list of AF technical reports and invited talks on contractual research are included. The report concludes with a brief description of ongoing research.

Table of Contents

I. Technical Reports

Titles and abstracts of technical reports issued during the '82-'83 support interval are listed below:

Report JQRST-1-82

"Review of Fundamental Processes for Matter-Radiation Interaction II"

January 28, 1982

Abstract

A concise review is presented of fundamental quantum electrodynamic processes which are relevant to X-ray lasers, grasers, and superpowerful lasers. Transition rates and cross sections are derived for atomic and free-electron Thomson scattering, Kramers-Heisenberg, and Raman scattering in the dipole approximation; Rayleigh scattering and Cerenkov effect. The report includes a table of reaction rates, cross sections, stopping power, and power spectra for all processes considered.

Report ZN-2-82

"Properties of a One-Dimensional Coulomb Gas"

May 11, 1982

Abstract

The BBKGY equations for N identical, impenetrable, charged particles which move in one dimension and lie in a charge neutralizing background, are shown to separate into N uncoupled equations for the sequence of N reduced distributions. The potential relevant to any subgroup of s adjoining particles is that of an

s-dimensional harmonic oscillator whose frequency is the plasma frequency of the aggregate. The s-particle spatial equilibrium distribution reveals that particle vibrations remain centered about fixed, uniformly distributed sites as ρ/T goes from zero to infinity, where ρ is particle density and T is temperature. Thus it is concluded that the system suffers no change in phase for all ρ and T.

Report JPP-3-82

"Kinetic Theory for a Short-Wavelength Lasing Plasma"

September 1, 1982

Abstract

A kinetic analysis is made of a reacting plasma dominated by three-body recombination and ionization, together with collisional and radiative excitation and de-excitation of atomic states. The plasma includes excited atoms, ions, electrons and photons. The kinetic theory yields rate equations for these species, together with explicit expressions for relevant rate coefficients. In the limit of spatial homogeneity and assuming atom and electron densities are close to equilibrium, an explicit form is obtained for the radiation absorption coefficient per unit length. A criterion is then constructed for population inversion. Application to a helium-like active medium (e.g. Al^{+11}) and hydrogen-like passive medium (e.g. Al^{+12}), at electron temperature of 300 eV, reveals that population inversion ensues at electron densities in excess of 10^{20} cm^{-3}. Algebraic solution of atomic state rate equations

demonstrates that the absorption coefficient grows insensitive to photon-atom interactions with increasing electron density.

Report R-4-82

"Exciton-Laser Amplifier"

December 1, 1982

Abstract

A laser-amplifying device is described which is based on the stimulated decay of excitons in a pure crystal. An estimate is made of the gain of the device. At a typical frequency the gain is found to be appreciably large thus suggesting practical application of the laser amplifier.

Report IJTP-1-83

"Induced Decay of Positronium and Grasers"

April 22, 1983

Abstract

The differential cross section and the total cross section for the stimulated decay of positronium by an incident photon of frequency ω is calculated as a function of the dimensionless variable $\xi = \hbar\omega/mc^2$. For $\xi >> 1$ the total cross section is found to decrease as ξ^{-2}. We also look at the particular case of positronium in a black-body radiation field. Expressions for the number of induced annihilations per second as functions of the dimensionless ratio mc^2/kT and the number of positronium atoms are obtained. It is found that this rate is proportional to $(kT/mc^2)^2$ for $kT \ll mc^2$ and to $(kT/mc^2)\ln(kT/mc^2)$ for $kT >> mc^2$.

The possibility of utilizing induced two-photon decay of positronium as a γ-ray laser at the wavelength $\gamma_c/2$ is examined, where γ_c is the Compton wavelength.

II. Invited Talks

A lecture tour given by the principal investigator during August, 1982 proved to be particularly valuable to contractual research. Here is a brief summary of the highlights of this trip:

At UCLA, John Dawson discussed a short wavelength lasing scheme based on the metastable 2P-1S transition in H-like atoms. He further suggested that one of his earlier papers might prove relevant to the speaker's recent investigation of strongly coupled plasmas. At the end of the colloquium there was keen discussion on the proper choice of ionization coefficients for studies of a dense, recombining plasma. Neville Luhmann described present plasma work at UCLA.

At UCSD, Bill Thomson suggested that use of the Saha equation is somewhat inconsistent with population inversion studies since this equation implies a Boltzmann population of excited states. J. H. Malmberg described recent ongoing experiments in effecting a one-component plasma through use of a magnetic mirror device. It is believed that the plasma so confined will eventually reach the large γ domain. (Here γ denotes the plasma parameter.)

On Aug. 11 traveler met with Norman Rostoker (UC Irvine). Dr. Rostoker expressed great interest in recent strongly coupled

plasma analyses. He pointed out that research related to plasmas with $\gamma \simeq 1$ would also prove valuable to the dynamics of the central region of the sun.

Attendance at all these talks was large and subsequent discussions were informative. There was valuable exchange of information with individual faculty members.

III. Ongoing Research

Present research is directed at the following areas:

1. Kinetic Theory of Strongly Coupled Plasmas.

   In recombination lasing the plasma parameter, $\gamma \simeq 1$, and the plasma is said to be strongly coupled. Kinetic properties of such plasmas permit the evaluation of parameters important to the design and implementation of short wavelength lasing.

2. Recombination Coefficient

   Recombination and ionization coefficients are also relevant to recombination lasing. Save for J.J. Thomson's elementary result for recombination, formulations of this coefficient rest on gross assumptions concerning properties of a plasma. Present research in this area seeks to construct the recombination coefficient from first principles. This result would be particularly relevant to non-equilibrium plasmas.

3. Lasing Criterion

   Research here seeks to obtain an explicit analytic expression for the integral criterion found by Heffernan and Liboff (Report No. JPP-3-82) for population inversion in a

dense recombining plasma. This newly constructed analytic form would easily permit graphical display which, in turn, would prove valuable to experimental research. Further study will generalize the Heffernan-Liboff criterion to include dynamics of the ion component of the plasma. Due to the complexity of this problem, influence of ion dynamics in the first formulation was minimal.